

# EL169835308

A  
+

Please type a plus sign (+) inside this box → ☐

PTO/SB/05 (12/97)  
Approved for use through 09/30/00. OMB 0651-0032

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE  
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

## UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No. MI22-1017 Total Pages 52

First Named Inventor or Application Identifier

Anand Srinivasan et al.

Express Mail Label No. EL169835308

### APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

1. ☒ Fee Transmittal Form  
(Submit an original, and a duplicate for fee processing)
2. ☒ Specification (Total Pages 20)  
(preferred arrangement set forth below)
  - Descriptive title of the Invention
  - Cross References to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to Microfiche Appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
3. ☐ Drawing(s) (35 USC 113) (Total Sheets ☐)
4. Oath or Declaration (Total Pages 3)
  - a. ☒ Newly executed (original or copy)
  - b. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 5 below]
    - i. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a. ☐ Computer Readable Copy
  - b. ☐ Paper Copy (identical to computer copy)
  - c. ☐ Statement verifying identity of above copies

### ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☒ 37 CFR 3.73(b) Statement (when there is an assignee) ☒ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☒ Information Disclosure Statement (IDS)/PTO-1449 ☒ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
14. ☐ Small Entity Statement filed in prior application, Status still proper and desired
15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. ☒ Other: Check

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: \_\_\_\_\_

### 18. CORRESPONDENCE ADDRESS

☐ Customer Number or Bar Code Label

(Insert Customer No. or Attach bar code label here)

or ☒ Correspondence address below

NAME	David G. Latwesen, Ph.D.				
ADDRESS	Wells, St. John, Roberts, Gregory & Matkin P.S. W. 601 First Ave., Suite 1300				
CITY	Spokane	STATE	WA	ZIP CODE	99201-3828
COUNTRY		TELEPHONE	(509) 624-4276	FAX	(509) 838-3424

Burden Hour Statement: This form is estimated take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

09/03/98

09/03/98

+

EL169835308

PTO/SB/17 (12-97)

Approved use through 09/30/00. OMB 0651-0032

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**FEE TRANSMITTAL**

Note Effective October 1, 1997.  
Patent fees are subject to annual revision.

**TOTAL AMOUNT OF PAYMENT** (\$) 1,466**Complete if Known**

Application Number	Filed Concurrently
Filing Date	
First Named Inventor	Anand Srinivasan et al
Group Art Unit	
Examiner Name	Unassigned
Attorney Docket Number	MI22-1017

**METHOD OF PAYMENT (check one)**

1. ☒ The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number 23-0925  
Deposit Account Name Wells, St. John, Roberts et al.

☒ Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17 ☐ Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance

2. ☐ Payment Enclosed:  
☐ Check ☐ Money Order ☐ Other

**FEE CALCULATION****1. FILING FEE**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
101 790	201 395	Utility filing fee	790
106 330	206 165	Design filing fee	
107 540	207 270	Plant filing fee	
108 790	208 395	Reissue filing fee	
114 150	214 75	Provisional filing fee	
<b>SUBTOTAL (1)</b>			<b>(\$ 790)</b>

**2. CLAIMS**

Total Claims	Extra	Fee from below	Fee Paid
34	-20 = 14	X 22 =	308
Independent Claims	7 - 3 = 4	X 82 =	328
Multiple Dependent Claims	0	X 270 =	0

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
103 22	203 11	Claims in excess of 20	
102 82	202 41	Independent claims in excess of 3	
104 270	204 135	Multiple dependent claim	
109 82	209 41	Reissue independent claims over original patent	
110 22	210 11	Reissue claims in excess of 20 and over original patent	
<b>SUBTOTAL (2)</b>			<b>(\$ 636)</b>

**FEE CALCULATION (continued)****3. ADDITIONAL FEES**

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
105 130	205 65	Surcharge - late filing fee or oath	0
127 50	227 25	Surcharge - late provisional filing fee or cover sheet	0
139 130	139 130	Non-English specification	0
147 2,520	147 2,520	For filing a request for reexamination	0
112 920*	112 920*	Requesting publication of SIR prior to Examiner action	0
113 1,840*	113 1,840*	Requesting publication of SIR after Examiner action	0
115 110	215 55	Extension for reply within first month	0
116 400	216 200	Extension for reply within second month	0
117 950	217 475	Extension for reply within third month	0
118 1,510	218 755	Extension for reply within fourth month	0
128 2,060	228 1,030	Extension for reply within fifth month	0
119 310	219 155	Notice of Appeal	0
120 310	220 155	Filing a brief in support of an appeal	0
121 270	221 135	Request for oral hearing	0
138 1,510	138 1,510	Petition to institute a public use proceeding	0
140 110	240 55	Petition to revive - unavoidable	0
141 1,320	241 660	Petition to revive - unintentional	0
142 1,320	242 660	Utility issue fee (or reissue)	0
143 450	243 225	Design issue fee	0
144 670	244 335	Plant issue fee	0
122 130	122 130	Petitions to the Commissioner	0
123 50	123 50	Petitions related to provisional applications	0
126 240	126 240	Submission of Information Disclosure Stmt	0
581 40	581 40	Recording each patent assignment per property (times number of properties)	40
146 790	246 395	Filing a submission after final rejection (37 CFR 1.129(a))	0
149 790	249 395	For each additional invention to be examined (37 CFR 1.129(b))	0
Other fee (specify) _____			0
Other fee (specify) _____			0

\* Reduced by Basic Filing Fee Paid

**SUBTOTAL (3)** (\$ 40)**SUBMITTED BY**

Typed or Printed Name David G. Latwesen, Ph.D.

Signature David G. Latwesen, Ph.D.

Date 9/13/98

**Complete (if applicable)**

Reg. Number 38533

Deposit Account User ID \_\_\_\_\_

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

**EL169835308**

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**APPLICATION FOR LETTERS PATENT**

\* \* \* \* \*

**METHODS OF FORMING INSULATING  
MATERIALS**

\* \* \* \* \*

**INVENTORS**

Anand Srinivasan  
Gurtej Sandhu  
Ravi Iyer

**ATTORNEY'S DOCKET NO. MI22-1017**

20250627 06:54:10

## Methods of Forming Insulating Materials

### TECHNICAL FIELD

The invention pertains to methods of forming insulating materials, such as, for example, materials comprising silicon oxide. In exemplary applications, the invention pertains to methods of forming boron and/or phosphorous doped materials comprising fluorine, silicon and oxygen.

### BACKGROUND OF THE INVENTION

Silicon oxide materials (such as, for example, silicon dioxide) are commonly used in semiconductor device fabrication as insulating materials. Silicon oxide materials can be formed by chemical vapor deposition (CVD) from appropriate precursors. An exemplary combination of precursors that can be utilized for forming silicon oxide materials is silane ( $\text{SiH}_4$ ) and hydrogen peroxide ( $\text{H}_2\text{O}_2$ ). Another precursor combination which can be utilized for forming silicon oxides is tetraethyl orthosilicate (TEOS) and ozone ( $\text{O}_3$ ).

Silicon oxide materials can be doped with one or both of boron and phosphorous to alter (lower) a dielectric constant of the material. The boron and/or phosphorous can be introduced into a silicon oxide material by, for example providing one or both of a boron-containing precursor material and a phosphorous precursor material in a CVD reaction chamber during deposition of the silicon oxide material.

1 Suitable phosphorous precursor materials include, for example,  $\text{PH}_3$  and  
2 tetraethoxy phosphine (TEPO). Suitable boron-containing precursors  
3 include, for example,  $\text{B}_2\text{H}_6$  and triethyl borane (TEB). An alternative  
4 method of introducing phosphorus and/or boron into a silicon oxide  
5 material is to implant one or both of phosphorus and boron into the  
6 material.

7 A characteristic of a deposited silicon oxide material is its so-  
8 called flow temperature. A flow temperature is a temperature at which  
9 the silicon oxide material will melt. Flow temperature can be an  
10 important characteristic of silicon oxide materials. For instance,  
11 incorporation of silicon oxide materials into semiconductor fabrication  
12 processes frequently involves melting and reflowing of the materials to  
13 increase planarity and obtain good coverage of the materials over  
14 underlying device structures. Films consisting essentially of silicon  
15 dioxide typically have flow temperatures of about  $1,100^\circ\text{C}$  or higher.  
16 Addition of boron or phosphorous to such films can reduce the flow  
17 temperatures to less than  $850^\circ\text{C}$ . It would be desirable to further  
18 reduce flow temperatures. Specifically, silicon oxide flow frequently  
19 occurs after provision of semiconductor devices in a semiconductor  
20 fabrication process. The high temperatures of silicon dioxide reflow can  
21 adversely affect such devices.

22 Another characteristic of silicon oxide materials is density. Denser  
23 materials generally have better flow properties than less dense materials.

Specifically, denser materials can frequently reflow over underlying nonplanar structures more quickly than can less dense silicon oxide materials. Accordingly, it would be desirable to develop methods for densifying silicon oxide materials.

## SUMMARY OF THE INVENTION

In one aspect, the invention encompasses a method of forming an insulating material. A substrate is provided within a reaction chamber together with reactants comprising Si, F and ozone. An insulating material comprising fluorine, silicon and oxygen is deposited onto the substrate from the reactants.

In another aspect, the invention encompasses a method of forming a boron-doped silicon oxide having Si-F bonds. A substrate is provided within a reaction chamber together with reactants comprising F-TES, a boron-containing precursor, and ozone. A boron-doped silicon oxide having Si-F bonds is deposited onto the substrate from the reactants.

In yet another aspect, the invention encompasses a method of forming a phosphorus-doped silicon oxide having Si-F bonds. A substrate is provided within a reaction chamber together with reactants comprising F-TES, a phosphorus-containing precursor, and ozone. A phosphorus-doped silicon oxide having Si-F bonds is deposited onto the substrate from the reactants.

1 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

2 This disclosure of the invention is submitted in furtherance of the  
3 constitutional purposes of the U.S. Patent Laws "to promote the  
4 progress of science and useful arts" (Article 1, Section 8).

5 The invention encompasses methods of chemical vapor deposition  
6 of insulating materials comprising fluorine, silicon and oxygen. In one  
7 aspect, the invention encompasses a method wherein a substrate is  
8 provided within a CVD reaction chamber together with reactants  
9 comprising Si, F and ozone. Subsequently, an insulating material  
10 comprising fluorine, silicon and oxygen is deposited onto the substrate  
11 from the reactants.

12 In an exemplary embodiment of the invention, the Si and F are  
13 comprised by a compound having an Si-F bond, such as, for example  
14 F-TES (triethoxy fluorosilane). The F-TES is preferably flowed into the  
15 reaction chamber at a rate from about 100 milligrams per  
16 minute (mg/min) to about 500 mg/min. The ozone is preferably flowed  
17 into the reaction chamber as a mixture with O<sub>2</sub> (the mixture preferably  
18 containing from about 5% to about 15% ozone, by volume), with an  
19 example being at a rate from about 1000 standard cubic centimeters per  
20 minute (scm) to about 5000 scm, and preferably about 2000 scm. In  
21 addition to the F-TES and ozone, a second silicon precursor can be  
22 flowed into the reaction chamber. Such second silicon precursor can  
23 comprise, for example, TEOS. In alternative embodiments of the

1 invention, the Si reactants can comprise TEOS and the F reactants can  
2 be comprised by molecules lacking Si.

3 Temperature of the substrate within the reaction chamber is  
4 preferably maintained at from about 400°C to about 700°C, and more  
5 preferably maintained at about 500°C. Pressure within the reaction  
6 chamber is preferably maintained at from about 1 Torr to about  
7 1 atmosphere, more preferably at from about 600 Torr to about  
8 1 atmosphere, and even more preferably at about 400 Torr. Most  
9 preferably, no plasma is present within the CVD reaction chamber to  
10 reduce costs and process complexity. However, it is noted that the  
11 invention encompasses embodiments wherein plasma is present within the  
12 reaction chamber during the deposition process.

13 Under the above-described exemplary conditions, a material  
14 comprising fluorine, silicon and oxygen is deposited onto the substrate  
15 at a rate from about 500 Å/minute to about 10,000 Å/minute, and is  
16 typically deposited at a rate of about 8,000 Å/minute. The deposited  
17 material comprises silicon oxide interspersed with Si-F bonds. The  
18 fluorine is generally present in such material to a concentration from  
19 about 0.1 atomic percent to about 10 atomic percent.

20 An advantage of incorporating fluorine into a silicon oxide  
21 material is that the fluorine can reduce the flow temperature of the  
22 material. For instance, it is found that fluorine incorporation into a  
23 silicon oxide material to an amount of from about 0.1 atomic percent



1 to about 10 atomic percent can reduce a flow temperature of the  
2 material. Specifically, it is found that a flow temperature of the  
3 material can be reduced by from about 50°C to about 100°C relative  
4 to a silicon oxide material that is identical to the fluorine-containing  
5 material in all respects except for lacking the fluorine.

6 Another advantage of incorporating Si-F bonds into a silicon oxide  
7 material (such as, for example, SiO<sub>2</sub> or borophosphosilicate glass) is that  
8 the fluorine can decrease a dielectric constant of the material.

9 Yet another advantage of incorporating fluorine into a silicon  
10 oxide material can be to reduce so-called fixed charge problems. Fixed  
11 charges result when one or more silicon atoms are bonded to less than  
12 four other atoms. In such circumstances, the silicon atoms can carry  
13 positively-charged electron density and shift a threshold voltage of a  
14 device incorporating the silicon atoms. Negatively charged fluorine  
15 atoms can interact with the positively-charged electron density to  
16 neutralize the density and alleviate fixed charge problems that would  
17 otherwise occur.

18 It is noted that F-TES has been utilized in the prior art in CVD  
19 processes for depositing silicon oxide materials. However, the F-TES  
20 was not utilized in combination with ozone. An aspect of the present  
21 invention is recognition that chemical vapor deposition of fluorine-  
22 containing silicon oxide from reactants comprising F-TES can be  
23 significantly improved if such reactants further comprise ozone.

Specifically, it is recognized that if the reactants comprise F-TES and lack ozone, very little fluorine is incorporated into a deposited silicon oxide. The advantageous effects of ozone have not been seen with other oxygen-containing precursors. Specifically, it is found that O<sub>2</sub> and/or H<sub>2</sub>O<sub>2</sub> work significantly less well than ozone as co-reactants with F-TES. In other words, if a comparable concentration of H<sub>2</sub>O<sub>2</sub> or O<sub>2</sub> is utilized under the above-described reaction conditions in substitution of ozone, the silicon oxide that is formed will have significantly less than 0.1 atomic percent fluorine incorporated therein. Such silicon dioxide will have higher flow temperatures and less density than a preferred silicon oxide formed according to a method of the present invention utilizing ozone in a chemical vapor deposition process. Also, H<sub>2</sub>O<sub>2</sub> can be more difficult to work with than ozone. For instance, it can be more difficult to accurately control an H<sub>2</sub>O<sub>2</sub> concentration in a reaction chamber than to control an ozone concentration in the chamber.

In other aspects of the invention, a fluorine-containing silicon oxide can be provided to be doped with, for example, one or both of phosphorous and boron. For instance, a phosphorous precursor can be incorporated as a reactant in a chemical vapor deposition process of the present invention to form an insulating material comprising fluorine, silicon, oxygen, and phosphorous. The phosphorous precursor can comprise, for example, TEPO. Preferably, the amount of phosphorous

1 incorporated into a fluorine-containing silicon oxide of the present  
2 invention is from about 1 atomic percent to about 10 atomic percent.

3 Exemplary conditions for incorporating phosphorous into a  
4 fluorine-containing silicon oxide utilizing a CVD process include:

5 a pressure within a CVD reaction chamber of from about 1 Torr  
6 to about 1 atmosphere;

7 a temperature of a substrate within the chamber of from about  
8 400°C to about 700°C;

9 a flow rate of F-TES into the reaction chamber of from about  
10 100 mg/min to about 500 mg/min;

11 a flow rate of ozone-containing gas (provided as a mixture of  
12 from about 5% to about 15% ozone in O<sub>2</sub>) of from about 1000 sccm  
13 to about 5000 sccm; and

14 a flow rate of TEPO in the reaction chamber of from about  
15 25 mg/min to about 400 mg/min.

16 As another example, boron can be incorporated into a fluorine-  
17 containing silicon oxide of the present invention by providing a boron-  
18 containing precursor as a reactant in a CVD reaction chamber. The  
19 boron-containing precursor can comprise, for example, TEB. The boron  
20 is preferably provided in a fluorine-containing silicon oxide of the  
21 present invention to a concentration of from about 1 atomic percent to  
22 about 10 atomic percent, and more preferably provided to a  
23 concentration of less than or equal to about 8 atomic percent.

1 An exemplary process for incorporating boron into a fluorine-  
2 containing silicon oxide utilizing a CVD process includes:

3 a pressure within a CVD reaction chamber of from about 1 Torr  
4 to about 1 atmosphere;

5 a temperature of a substrate within the chamber of from about  
6 400°C to about 700°C;

7 a flow rate of F-TES into the reaction chamber of from about  
8 100 mg/min to about 500 mg/min;

9 a flow rate of ozone-containing gas (provided as a mixture of  
10 from about 5% to about 15% ozone in O<sub>2</sub>) of from about 1000 sccm  
11 to about 5000 sccm; and

12 a flow rate of TEB into the reaction chamber of from about  
13 25 mg/min to about 400 mg/min.

14 In yet another exemplary application, a fluorine-containing silicon  
15 oxide of the present invention can be provided to be doped with both  
16 boron and phosphorous. Preferably, the boron and phosphorous atoms  
17 are together provided to a concentration of from about 3 atomic percent  
18 to about 12 atomic percent within the fluorine-containing silicon oxide.  
19 An exemplary composition of the silicon oxide comprises about 3%  
20 boron, about 7% phosphorous, and about 2% fluorine (by atomic  
21 percent).

22 Exemplary conditions for forming the boron and phosphorous  
23 doped fluorine-containing silicon oxide include:

1 a pressure within a CVD reaction chamber of from about 1 Torr  
2 to about 1 atmosphere;

3 a temperature of a substrate within the chamber of from about  
4 400°C to about 700°C;

5 a flow rate of F-TES into the reaction chamber of from about  
6 100 mg/min to about 1000 mg/min;

7 a flow rate of ozone-containing gas (provided as a mixture of  
8 from about 5% to about 15% ozone in O<sub>2</sub>) of from about 1000 sccm  
9 to about 8000 sccm;

10 a flow rate of TEPO in the reaction chamber of from about  
11 25 mg/min to about 400 mg/min; and

12 a flow rate of TEB into the reaction chamber of from about  
13 25 mg/min to about 400 mg/min. In preferred embodiments, the  
14 pressure is from about 10 Torr to about 700 Torr.

15 In each of the above-described embodiments, the CVD reaction  
16 chamber referred to is a single wafer, cold wall chamber. The invention  
17 encompasses embodiment utilizing other types of reaction chambers.

18 In compliance with the statute, the invention has been described  
19 in language more or less specific as to structural and methodical  
20 features. It is to be understood, however, that the invention is not  
21 limited to the specific features shown and described, since the means  
22 herein disclosed comprise preferred forms of putting the invention into  
23 effect. The invention is, therefore, claimed in any of its forms or

1 modifications within the proper scope of the appended claims  
2 appropriately interpreted in accordance with the doctrine of equivalents.  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23

**CLAIMS:**

1. A method of forming an insulating material comprising:  
providing a substrate within a reaction chamber;  
providing reactants comprising silicon, fluorine and ozone within  
the reaction chamber; and

depositing an insulating material comprising fluorine, silicon and  
oxygen onto the substrate from the reactants.

2. The method of claim 1 wherein the depositing occurs  
without a plasma being present in the reaction chamber.

3. The method of claim 1 wherein the depositing occurs with  
a plasma being present in the reaction chamber.

4. The method of claim 1 wherein the silicon and fluorine of  
the reactants are comprised within a common molecule.

5. The method of claim 1 wherein the silicon and fluorine of  
the reactants are comprised within a common molecule having an Si-F  
bond.

1           6.    The method of claim 1 wherein the silicon and fluorine of  
2 the reactants are comprised by triethoxy fluorosilane.

3  
4           7.    The method of claim 1 wherein the fluorine in the  
5 insulating material is present in Si-F bonds.

6  
7           8.    The method of claim 1 wherein the fluorine in the  
8 insulating material is present at a concentration of from about  
9 0.1 atomic percent to about 10 atomic percent.

10  
11          9.    The method of claim 1 wherein the insulating material is  
12 deposited at a rate of from about 1000 Å/minute to about  
13 7000 Å/minute.

14  
15          10.   The method of claim 1 further comprising maintaining a  
16 pressure within the reaction chamber at from about 1 Torr to about  
17 1 atmosphere during the depositing.

18  
19          11.   The method of claim 1 further comprising maintaining a  
20 pressure within the reaction chamber at from greater than 400 Torr to  
21 about 1 atmosphere during the depositing.



12. The method of claim 1 further comprising maintaining a temperature of the substrate at from about 400°C to about 700°C during the depositing.

13. The method of claim 1 wherein the reactants further comprise phosphorus, and wherein the insulating material comprises fluorine, silicon, oxygen and phosphorus.

14. The method of claim 1 wherein the reactants further comprise boron, and wherein the insulating material comprises fluorine, silicon, oxygen and boron.

15. The method of claim 1 wherein the reactants further comprise boron and phosphorus, and wherein the insulating material comprises fluorine, silicon, oxygen, boron and phosphorus.

16. The method of claim 1 wherein the reactants comprise a molecule that includes both Si and F, and another molecule that includes Si without F.

17. The method of claim 1 wherein the reactants comprise triethoxy fluorosilane and tetraethyl orthosilicate.

1 18. A method of forming a silicon oxide having Si-F bonds,  
2 comprising:

3 providing a substrate within a reaction chamber;

4 providing reactants comprising ozone and a precursor having Si-F  
5 bonds; and

6 depositing a silicon oxide having Si-F bonds onto the substrate  
7 from the reactants.

8  
9 19. The method of claim 18 wherein the precursor having Si-F  
10 bonds is triethoxy fluorosilane.

11  
12 20. The method of claim 18 wherein the depositing occurs  
13 without a plasma being present in the reaction chamber.

14  
15 21. A method of forming a boron-doped silicon oxide having  
16 Si-F bonds, comprising:

17 providing a substrate within a reaction chamber;

18 providing reactants comprising triethoxy fluorosilane, a boron-  
19 containing precursor, and ozone within the reaction chamber; and

20 depositing a boron-doped silicon oxide having Si-F bonds onto the  
21 substrate from the reactants.

1           22. The method of claim 21 wherein the boron-containing  
2 precursor is triethyl borane.

3  
4           23. A method of forming a phosphorus-doped silicon oxide  
5 having Si-F bonds, comprising:

6           providing a substrate within a reaction chamber;

7           providing reactants comprising triethoxy fluorosilane, a phosphorus-  
8 containing precursor, and ozone within the reaction chamber; and

9           depositing a phosphorus-doped silicon oxide having Si-F bonds  
10 onto the substrate from the reactants.

11  
12           24. The method of claim 23 wherein the phosphorus-containing  
13 precursor is tetraethoxy phosphine.

1           25. A method of forming a boron and phosphorus doped silicon  
2 oxide having Si-F bonds, comprising:

3           providing a substrate within a reaction chamber;

4           providing reactants comprising triethoxy fluorosilane, a boron-  
5 containing precursor, a phosphorus-containing precursor and ozone within  
6 the reaction chamber; and

7           depositing a boron and phosphorus doped silicon oxide having Si-F  
8 bonds onto the substrate from the reactants, the depositing occurring  
9 without a plasma being present in the reaction chamber.

10  
11           26. The method of claim 25 wherein the boron-containing  
12 precursor is triethyl borane.

13  
14           27. The method of claim 25 wherein the phosphorus-containing  
15 precursor is tetraethoxy phosphine.

16  
17           28. The method of claim 25 wherein the phosphorus-containing  
18 precursor is tetraethoxy phosphine and the boron-containing precursor  
19 is triethyl borane.

1           29. A method of forming a silicon and oxygen containing  
2 insulating material having reduced flow temperatures, comprising:

3           providing a substrate within a reaction chamber;

4           providing reactants comprising Si, F and ozone within the reaction  
5 chamber; and

6           depositing a first insulating material containing fluorine, silicon  
7 and oxygen onto the substrate from the reactants, the first insulating  
8 material having reduced flow temperatures as compared to another  
9 silicon and oxygen containing insulating material deposited under the  
10 same conditions but without having fluorine in the reactants.

11  
12           30. The method of claim 29 wherein reactants further comprise  
13 at least one of a phosphorus-containing precursor and a boron-containing  
14 precursor, and wherein the first insulating material further comprises at  
15 least one of boron and phosphorus.

16  
17           31. The method of claim 29 wherein the Si and F are  
18 comprised by triethoxy fluorosilane.

1           32. A method of forming a silicon and oxygen containing  
2 insulating material having increased density, comprising:

3           providing a substrate within a reaction chamber;

4           providing reactants comprising Si, F and ozone within the reaction  
5 chamber; and

6           depositing a first insulating material containing fluorine, silicon  
7 and oxygen onto the substrate from the reactants, the first insulating  
8 material having increased density as compared to another silicon and  
9 oxygen containing insulating material deposited under the same  
10 conditions but without having fluorine in the reactants.

11  
12           33. The method of claim 32 wherein reactants further comprise  
13 at least one of a phosphorus-containing precursor and a boron-containing  
14 precursor, and wherein the first insulating material further comprises at  
15 least one of boron and phosphorus.

16  
17           34. The method of claim 32 wherein the Si-F precursor is  
18 triethoxy fluorosilane.

1     **ABSTRACT OF THE DISCLOSURE**

2             In one aspect, the invention includes a method of forming an  
3     insulating material comprising: a) providing a substrate within a reaction  
4     chamber; b) providing reactants comprising a Si, F and ozone within the  
5     reaction chamber; and c) depositing an insulating material comprising  
6     fluorine, silicon and oxygen onto the substrate from the reactants. In  
7     another aspect, the invention includes a method of forming a boron-  
8     doped silicon oxide having Si-F bonds, comprising: a) providing a  
9     substrate within a reaction chamber; b) providing reactants comprising  
10    Triethoxy fluorosilane, a boron-containing precursor, and ozone within  
11    the reaction chamber; and c) depositing a boron-doped silicon oxide  
12    having Si-F bonds onto the substrate from the reactants. In yet another  
13    aspect, the invention includes a method of forming a phosphorus-doped  
14    silicon oxide having Si-F bonds, comprising: a) providing a substrate  
15    within a reaction chamber; b) providing reactants comprising triethoxy  
16    fluorosilane, a phosphorus-containing precursor, and ozone within the  
17    reaction chamber; and c) depositing a phosphorus-doped silicon oxide  
18    having Si-F bonds onto the substrate from the reactants.

**EL169835308****DECLARATION OF JOINT INVENTORS FOR PATENT APPLICATION**

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: Methods of Forming Insulating Materials, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations §1.56.

**PRIOR FOREIGN APPLICATIONS:**

I hereby state that no applications for foreign patents or inventor's certificates have been filed prior to the date of execution of this declaration.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under



1 Section 1001 of Title 18 of the United States Code and that such willful  
2 false statement may jeopardize the validity of the application or any  
3 patent issued therefrom.

4 \* \* \* \* \*

5 Full name of inventor: Anand Srinivasan

6 Inventor's Signature: 

7 Date: 9/3/98

8 Residence: Boise, ID

9 Citizenship: India

10 Post Office Address: 670 S. Clearwater, #201  
Boise, ID 83712

11 \* \* \* \* \*

12  
13 Full name of inventor: Gurtej Sandhu

14 Inventor's Signature: 

15 Date: 9/3/98

16 Residence: Boise, ID

17 Citizenship: Great Britain

18 Post Office Address: 2964 E. Parkriver Drive  
Boise, ID 83706

\* \* \* \* \*

Full name of inventor: **Ravi Iyer**Inventor's Signature: *Ravi Iyer*Date: 9/3/98Residence: **Boise, ID**Citizenship: **India**Post Office Address: **5600 S. Fuchsia Ln.  
Boise, ID 83716**

**EL169835308****IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Application Serial No. .... Filed herewith  
Filing Date .... Filed herewith  
Inventor ..... Anand Srinivasan et. al.  
Assignee ..... Micron Technology, Inc.  
Group Art Unit ..... Unknown  
Examiner ..... Unknown  
Attorney's Docket No. .... MI22-1017  
Title: Methods Of Forming Insulating Materials

**POWER OF ATTORNEY BY ASSIGNEE AND**  
**CERTIFICATE BY ASSIGNEE UNDER 37 CFR §3.73(b)**

To: Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

**MICRON TECHNOLOGY, INC.**, the Assignee of the entire right, title and interest in the above-identified patent application by assignment attached hereto, hereby appoints the attorneys and agents of the firm of **WELLS, ST. JOHN, ROBERTS, GREGORY & MATKIN P.S.**, listed as follows:

Richard J. St. John	Reg. No. 19,363
David P. Roberts	Reg. No. 23,032
Randy A. Gregory	Reg. No. 30,386
Mark S. Matkin	Reg. No. 32,268
James L. Price	Reg. No. 27,376
Deepak Malhotra	Reg. No. 33,560
Mark W. Hendricksen	Reg. No. 32,356
David G. Latwesen	Reg. No. 38,533
George G. Grigel	Reg. No. 31,166
Keith D. Grzelak	Reg. No. 37,144
John S. Reid	Reg. No. 36,369
Lance R. Sadler	Reg. No. 38,605
James D. Shaurette	Reg. No. 39,833

1 and also attorneys Michael L. Lynch (Reg. No. 30,871) and Lia Pappas  
2 Dennison (Reg. No. 34,095) of Micron Technology, Inc., as its attorneys with  
3 full power of substitution to prosecute this application and transact all  
4 business in the Patent and Trademark Office connected therewith.

5 The Assignee certifies that the above-identified Assignment has been  
6 reviewed and to the best of Assignee's knowledge and belief, title is in the  
7 Assignee.

8 Please direct all correspondence regarding this application to:

9 Wells, St. John, Roberts, Gregory & Matkin P.S.  
10 Attn: David G. Latwesen, Ph.D.  
601 W. First Avenue, Suite 1300  
Spokane, WA 99201-3828

11 Telephone: (509) 624-4276  
12 Facsimile: (509) 838-3424

13 MICRON TECHNOLOGY, INC.

14  
15 Dated: 9/3/98

By: 

16 Name: Michael L. Lynch, Esq.  
17 Title: Chief Patent Counsel  
18  
19  
20  
21  
22  
23